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VERIFICATION OF TRANSLATION

I hereby declare and state that I am knowledgeable of each of the German and English languages and that I made and reviewed the attached translation of a patent application entitled "Method of Rough-Honing the Circumferential Surface of a Bore" from the German language into the English language, and that I believe my attached translation to be accurate, true, and correct to the best of my knowledge and ability.

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Method of Rough-Honing the Circumferential Surface of a Bore

Description

The invention relates to a method of rough-honing the circumferential surface of a bore. Based on the possible metal-removing capacities and tool lives, it has already been proposed that fine-boring be replaced by rough-honing. In this way, the advantages of the honing process can be more fully utilized. In order, however, to achieve quality corrections in terms of angularity and positional precision comparable to those when using fine-spindle-machining, it is not possible to transfer the normal degrees of freedom for honing tool and workpiece to rough-honing.

The concept of employing rough-honing instead of fine boring thus provides for a fixed alignment of the tool axis as well as fixed clamping of the workpiece. Based on the index position, the workpiece can be received with sufficient accuracy relative to the tool axis. Based on top and bottom tool guidance, a rigid alignment of the tool at the specified position of the bore can be achieved, with the result that the angular axial position of the tool is stable. The difference in regard to position and angular position of the tool axis to the pre-machined bore axis represents the required correction potential.

At the start of the rough-honing process, the honing stones only partially work the circumferential surface of the bore. As more and more material is removed, cutting expands to the full area of the entire bore. Since generally a varying amount of material is removed locally, a new bore center is created which is identical to the tool center. During the initial cut, only a few honing stones transfer the contact pressure to the bore wall. This therefore requires a form-locking feed device, i.e., an incremental feed. The feed functions consist in the intermittent feed motion, composed of the parameter defined from the feed phase and the feed pause interval in which the previously developed feed pressure diminishes.

This method of rough-honing, which is known from the article by U. Klink/G. Flores "Honing CGI Cylinder Bores" [*Honen von Zylinderbohrungen aus GGV*] in the journal *WB. Werkstatt und Betrieb*, Volume 133, 2000, Issue 4, Carl Hanser Verlag,

Munich, can be implemented only with those workpieces in which very specific requirements are met in regard to accessibility of the bores, with the result that significant limits are placed on the method's scope of application. It is usable for continuous bores but not for blind-hole bores, which are predominantly encountered in, for example, cylinder barrels.

This goal of this invention is therefore to create a method of rough-honing the circumferential surface of a bore that has universal applicability.

This goal is achieved by a method having the features of Claim 1.

This invention enables even those bores accessible only from one side to be machined in workpieces by means of rough-honing. At the same time, both correction of the bore position relative to the index bore and correction of the angular position of the bore axis are possible. This latter aspect is of considerable importance, in particular, in regard to engine blocks since angular precision relative to the crankshaft axis is critical. Machining by honing begins first as a partial cut in which the tool is not yet in complete contact. Only when the entire surface of the bore has been machined and the honing stones contact both sides has the full cut been achieved.

A preferred further development of the method provides that the reciprocating motion of the honing tool be effected by a slide unit, at least during the machining of the section of the bore facing away from the slide unit, such that the working spindle is moved by the slide unit alternately in terms of its longitudinal axis. Independently of its instantaneous position, the slide unit provides a uniform guide stability for the spindle. Here the honing spindle is located at its top end position. The employed combination of slide unit with mounted honing spindle provides high stability for the slide unit in the partial cut, as well as high stroke speeds in the full cut, as enabled by a honing spindle. Based on this design, an overhung-mounted working spindle can be minimized in regard to its overall length. What is meant by minimal overall length here is that upon reaching the tool's lower travel reversal point along with the maximum conventional overrun length, the tool support is located just in front of the upper bore edge. This corresponds to the minimum overall length, below which value this dimension cannot fall, and by which the bore length to be honed is specified.

It is viewed as being advantageous if during an initially effected partial cut an electromechanical feed of the honing stones is implemented with defined pause intervals.

The switch from partial cut to the full cut parameter can be triggered by monitoring the power input since the torque increases with the full-area application of the cutting tools. This can also be a signal to retire the slide movement such that as a result the reciprocating motion is initiated by the honing spindle, and the alternating longitudinal motion by the honing spindle is effected in the full cut. The use of the slide unit as the stroke-drive enables the stability of the spindle to be significantly increased.

During full-cut honing, an electromechanical incremental feed is effected while the feed force acting on the honing stones is monitored. The result is a combination of displacement-controlled and force-controlled feed. In another further development of the method, a first honing stone set is impinged upon during the partial cut, while the full cut is implemented with a second honing stone set.

The following explains one embodiment of the invention in greater detail based the drawings.

Figure 1 shows a section through an engine block and a honing tool, illustrated schematically, located above the block;

Figure 2 shows a section through the engine block of Figure 1 with the honing tool close to the end of the machining operation;

Figure 3 shows a radial section through a bore and the honing tool at the start of machining.

Figure 4 is a perspective view of a section of a bore wall with the transition from turning profile to honing profile.

Figure 5 is a developed view of a section of the bore wall of Figure 4.

Figure 1 shows a workpiece 1 which in this embodiment is an engine block. This workpiece has multiple bores 2 which are provided in the form of cylinder bores and have a circumferential surface 3 which is to be machined. Each bore 2 has a longitudinal axis M_B. Multiple crankshaft bearings 4 are provided in the lower section of engine block 1, the bearings having a common axis $_K$, i.e., the longitudinal axis of the crankshaft M_K. Engine block 1 is accommodated in a precise manner on the workpiece carrier 8 by indexing pins 9 so that the relative location of workpiece 1 is precisely positioned.

In addition, the correction of the angular position of the bore axis entails an angularly correct accommodation of the workpiece. It is therefore necessary that axes M_A and M_K can be oriented at right angles to each other.

Shown above workpiece 1 is a honing tool 5 which is located on an overhung-mounted working spindle 6 and comprises multiple honing stones 7 which are provided to machine the circumferential surface 3 of bores 2. Working spindle 6, and thus honing tool 5 itself, has a longitudinal axis M_A, wherein Figure 1 reveals that before machining by honing tool 5 an offset S occurs between longitudinal axis of the working spindle M_A and the longitudinal axis of the bore M_B . Apart from a few exceptions, this offset of the axes is present which measures up to 0.3 mm.

As a result of the rough-honing operation, it is possible to implement an appropriate removal of material while simultaneously eliminating offset S, thereby displacing longitudinal axis of the bore M_B to the extent that this axis corresponds exactly to the position actually required in engine block 1, thereby approaching longitudinal axis M_A. The result is that at the same time a high angular precision is achieved for the longitudinal axis of M_B of bore 2 [relative to][1] the longitudinal axis of crankshaft M_K.

To the extent offset S of the longitudinal axis of the working spindle M_A relative to the longitudinal axis of the bore M_B is of a magnitude by which the free insertion of honing tool 5 into bore 2 is prevented, the longitudinal axis of the working spindle M_A is deflected at a corresponding angle in order thereby to enter bore 2 and machine the bore's circumferential surface 3. During machining, not only is offset S of longitudinal axes M_A and M_B relative to each other eliminated but so is any angle assumed by longitudinal axis M_A that might also be caused by the production tolerances of engine block 1.

Figure 2 shows a section through engine block 1 of Figure 1, wherein, however, honing tool 5 is located in bore 2 and the situation is illustrated near the end of machining. In regard to identical parts, the reference notations are the same as those of Figure 1. It is evident in Figure 2 that working spindle 6 has been passed through a slide unit 10, wherein slide unit 10 can be locked for a certain segment of the process (for example, working in the partial cut) with working spindle 6 in the longitudinal axis of working spindle 6 or of longitudinal axis M_A. As illustrated in Figure 2, the rough-honing operation has already progressed to the point that the longitudinal axis of the working spindle M_A is coaxial with the longitudinal axis of the bore M_B such that finally a uniformly honed circumferential surface is generated. In this first operating phase, it is advantageous to lock working

[1] Translators note: original syntax unclear; meaning interpolated from context.

spindle 6 longitudinally within slide unit 10 and to have the reciprocating motion effected by slide unit 10 since this approach keeps the free end of working spindle 6 projecting from slide unit 10 as short as possible, thereby achieving a high level of flexural rigidity in working spindle 6. Accordingly, during the first phase of the process, working spindle 6 remains at its upper end position within slide unit 10, thereby providing stabilization against lateral cutting forces. This aspect also achieves higher guiding precision and higher normal force stability.

Only during the full cut does slide unit 10 remain in a fixed position, while working spindle 6 effects a reciprocating motion relative to slide unit 10 which is at rest. At the same time, it is possible to operate at higher stroke speeds so that rough-honing in the full cut is possible within short machining times.

Figure 3 shows a radial section through bore 2 and honing tool 5 at the start of machining. It is evident here that longitudinal axis M_B of bore 2 has a displacement or an offset S relative to longitudinal axis M_A of the working spindle, or of honing tool 5. A feed rod 11 is centrically located within honing tool 5, which rod acts through feed keys 12 on honing stones 7. Feed keys 12 can be pressed outward by feed rod 11, thereby also causing honing stones 7 to effect a radially outward-directed motion.

As Figure 3 shows, at the start of machining only a part of honing tool 5 is applied to circumferential surface 3 of bore 2 such that in terms of the rough-honing operation initially only a partial cut is effected in which honing tool 5 is not fully in contact. The removal of material only from a section of circumferential surface 3 results in the bore center, and thus the longitudinal axis of the bore M_B, being displaced such that longitudinal axis of the working spindle M_A and longitudinal axis of the bore M_B approach each other. Only when bore 2 is being machined everywhere with complete coverage, thus eliminating offset S between the axes, is bore 2 machined everywhere with complete coverage such that honing stones 7 contact the entire circumference of bore 2. As a result, the full cut is achieved by which uniformly honed circumferential surface 3 is then generated.

Figure 4 is a perspective view of a section of the bore wall, or of circumferential surface 3 of cylinder bore 2. Here a section 13 with a turning profile in the left region of bore 2 can be seen, while a section 14 with honing profile in the right region of bore 2 is present. This illustration clearly reveals that in the initially effected partial cut only a

certain section of circumferential surface 3 is machined by rough-honing and that there is a transition from the turning profile to the honing profile.

Figure 5 is a developed view of a section of the bore wall in Figure 4 which also clearly reveals the transition from the turning profile to the honing profile.